

# PROJECT facts

U.S. DEPARTMENT OF ENERGY  
OFFICE OF FOSSIL ENERGY  
NATIONAL ENERGY TECHNOLOGY LABORATORY

Sequestration

03/2006



## INTERNATIONAL COLLABORATION ON CO<sub>2</sub> SEQUESTRATION

### Background

The concentration of CO<sub>2</sub> in the atmosphere has been increasing since the start of the industrial revolution due, in large part, to increased fossil fuel combustion. Because CO<sub>2</sub> is a greenhouse gas, its increased atmospheric concentration has generated concern about global climate change. One suggestion to address this issue is to capture CO<sub>2</sub> from stationary power sources and introduce it directly into the oceans, thus bypassing the slower biological and solubility cycles by which approximately 80 percent of the CO<sub>2</sub> that we currently emit will ultimately be absorbed by the oceans.

Among the issues requiring consideration before sequestering CO<sub>2</sub> in the oceans would become feasible, is the need to obtain high initial dilution of CO<sub>2</sub> in ocean water in order to minimize the excess concentration of dissolved inorganic carbon and, hence, the associated increase in pCO<sub>2</sub> and decrease in pH to which the aquatic biota would be exposed.

Although the overall project involves eleven tasks, the emphasis at MIT will be on the following four tasks: (1) preparation and testing of equipment for measurement and monitoring; (2) observing the performance of ocean field experiments; (3) analysis of data acquired during the experiments; and (4) collation of overall results obtained in the field experiments. This international effort involves five nations (the U.S., Japan, Norway, Canada, and Australia) and one private corporation (ABB of Switzerland). In the project agreement, the Massachusetts Institute of Technology (MIT) is designated as the Implementing Research Organization for the DOE.

Two-phase plumes play an important role in various scenarios for ocean sequestration (dispersing CO<sub>2</sub> as a buoyant liquid from either a bottom-mounted or ship-towed pipeline or as a negatively buoyant hydrate from a ship). Despite much research on related applications, understanding of these CO<sub>2</sub> flows is incomplete, especially concerning the phenomenon of plume peeling in a stratified ambient environment. To address this deficiency, a laboratory facility was built to obtain fundamental measurements of CO<sub>2</sub> plume behavior.

### Primary Project Goal

The overall goal of this international effort toward reduction of greenhouse gases via ocean sequestration of CO<sub>2</sub> is to (1) investigate the technical feasibility of this approach to carbon management; (2) improve our understanding of the potential environmental impacts of ocean sequestration of CO<sub>2</sub>; and (3) to minimize impacts associated with this sequestration technology on the marine biota.

MIT's primary activity, as part of this overall effort, is to conduct a series of laboratory experiments and to develop a mathematical model to describe a plume of liquid CO<sub>2</sub> dispersed from a nozzle in the deep ocean.



## COST

**Total Project Value**  
1,100,000

**DOE/Non-DOE Share**  
\$1,100,000 / \$0

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## WEBSITE

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## Objectives

- To prepare and test instrumentation for the measurement and monitoring of CO<sub>2</sub> injection into the oceans.
- To better understand the phenomena occurring in two-phase plumes.
- To observe the performance of ocean field experiments.
- To analyze data acquired during field experiments.
- To collate overall results obtained from field experiments.
- To develop and validate a model of the behavior of CO<sub>2</sub> injected into the ocean.
- To participate in project management as a member of the Technical Committee.

## Accomplishments

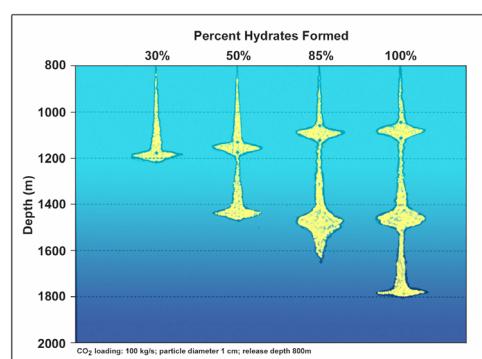
Quantitative data are being compared with a new analytical model which treats the flow as an upward-moving inner plume, coupled with an annular, downward flowing outer plume. The model also includes CO<sub>2</sub>-specific features, such as bubble/droplet mass transfer, solute dissolution effects on plume buoyancy, and change in total CO<sub>2</sub> concentration and pH. This double plume model was used to explore the fate of solid CO<sub>2</sub> hydrate particles released into the ocean for the purpose of CO<sub>2</sub> sequestration. Previous modeling results have been compared with those of researchers from Japan and Norway.

Mathematical models have been used to examine three dilution strategies that promote mixing in the longitudinal, lateral, and vertical directions. A point release of negatively buoyant solid CO<sub>2</sub> hydrate particles from a moving ship would achieve acceptable dilution near the source, while subsequent concentrations would be very low due to longitudinal mixing afforded by the ship's speed. A long, bottom-mounted diffuser, discharging buoyant liquid CO<sub>2</sub> droplets, can be designed for high lateral mixing, resulting in arbitrarily small near source concentrations, but because the resulting near field plume would be very wide, subsequent dilution would be slow. A stationary point release of hydrate particles achieves good vertical mixing, due to the negatively buoyant plume effect, resulting in intermediate local and subsequent concentrations.

## Benefits

The consequences from global climate change and rising sea levels are potentially severe. Therefore, it is important to explore all options for mitigating the buildup of greenhouse gases in the atmosphere. One possibility is sequestration in the oceans. However, much more complete understanding of the environmental effects of this option need to be developed before ocean sequestration of CO<sub>2</sub> can be implemented. This project is aimed at providing that understanding.

While directly applicable to ocean carbon sequestration, results developed by this project will also provide guidance for the effective three-dimensional dispersal of other materials, such as nutrients for open water aquaculture and flocculants or algaecides for improving water clarity in reservoirs or town ponds.



A schematic depicting plume model results for sinking plumes of different hydrate composition